Chapter 16
Ultraviolet Oxidation

16-1. General.

The process of ultraviolet (UV) oxidation and its applications are described in the chapter's first section. The second portion of the chapter is a hazard analysis with controls and control points listed.

16-2. Technology Description

a. Process.

UV oxidation is a destructive process that photochemically oxidizes organic and explosive constituents in wastewater by the addition of strong oxidizers, which are activated by irradiation with UV light. The oxidation reactions are achieved through the synergistic action of UV light, in combination with ozone (O_3) and/or hydrogen peroxide (H_2O_2) and/or other catalysts and reagents. Lamps that generate UV light shine on the flow path for the water stream, and the ozone and/or peroxide are injected upstream of the lamps. If complete mineralization is achieved, the final products of the oxidation are carbon dioxide, water, and salts. UV oxidation can use hydrogen peroxide alone, ozone alone, or a combination of hydrogen peroxide and ozone together to treat the aqueous stream.

The main advantage of UV oxidation is that it is a destructive process, as opposed to air stripping or carbon absorption, in which contaminants are extracted and concentrated in a separate phase. The UV oxidation process can be configured in batch or continuous flow modes, depending on the required flow and concentrations. See Figure 16-1.

b. Applications.

The process is effective only for relatively clear aqueous streams. Turbidity in the water will prevent the UV light from fully penetrating the water stream.

For additional information on similar processes, see the Precipitation (Chapter 15) and Chemical Reduction/Oxidation (Chapter 18) technologies.

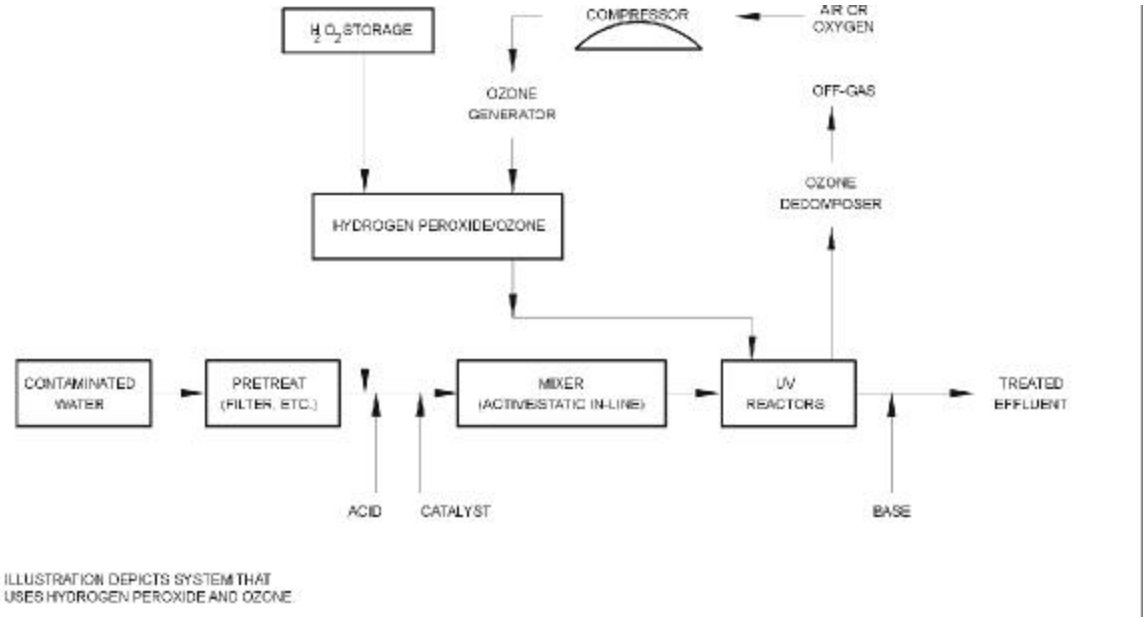

FIGURE 16-1. TYPICAL PROCESS FLOW FOR ULTRAVIOLET OXIDATION

16-3. Hazard Analysis.

Principal unique hazards associated with ultraviolet oxidation, methods for control, and control points are described below.

a. Physical Hazards.

(1) Heated Surfaces.

Description: Certain components of UV treatment systems, such as the UV lamps and the ozone generator, may generate heated surfaces that may cause burns to unprotected skin.

Control: Controls for heated surfaces include
- Insulate or cool surfaces either by ventilation or through a heat exchanger.
- Wear insulated gloves to prevent thermal burns.

CONTROL POINT: Design, Operations, Maintenance

(2) Electrocution.
Description: UV oxidation systems utilize high-voltage mercury lamps that may operate on voltages up to 3,000 volts. Breakage of the lamps may cause electrocution.

Control: Controls for electrocution include
- Verify that drawings indicate the hazardous area classifications as defined in National Fire Protection Association (NFPA) 70-500-1 through 500-10.
- Use controls, wiring, and equipment that meet the requirements of EM 385-1-1, Section 11.G and NFPA 70 for the identified hazard areas.
- Use grounded or ground fault interrupter circuit (GFIC)-protected equipment if required by EM 385-1-1, Section 11 or NFPA 70.
- Equip UV lamp cover panels with interlocks that de-energize the system when doors are opened.

CONTROL POINT: Design, Construction, Operations, Maintenance

(3) Explosion and Combustion Hazards.
Description: Although hydrogen peroxide solutions (27-52 percent) are not combustible, as strong oxidizers they can greatly intensify combustion. They also present an explosion hazard because of violent decomposition when heated or contaminated with oxidizable materials including iron, copper, brass, bronze, copper, and other metals (see Material Safety Data Sheets for complete listing). Contact with reducing agents or organic and combustible materials (wood, paper) may cause immediate spontaneous ignition.

Control: Controls for explosion include
- Implement a plant-specific lock-out/tag-out program designed after the requirements of 29 CFR 1910.147 for maintenance procedures.
- Implement a plant-specific hazard communication program for plant operators on the reactive properties of hydrogen peroxide. Design in compliance with the requirements of 29 CFR 1910.1200.
- Store hydrogen peroxide solutions in their original containers in a cool, clean, fire-resistant area away from combustible materials, catalytic metals, direct sunlight, and other potential sources of heat and/or ignition.
- Maintain the purity of the solution.
- Do not return unused material to its storage container after removal.
- Select, design, and maintain all equipment in contact with hydrogen peroxide solutions to minimize reactive hazards.
- Use secondary containment in storage areas.
- Supply an ample source of water for handling spills.

CONTROL POINT: Design, Operations, Maintenance

(4) Confined Spaces.

Description: UV oxidation facilities may contain vaults and vessels that require entry as a normal part of operation and maintenance. These spaces have the potential to contain hazardous atmospheres and/or engulfment dangers due to the nature of materials and equipment used in the treatment process.

Control: Controls for confined spaces include

- Eliminate confined space in the design where possible (designers). If confined spaces cannot be eliminated, designers should seek to minimize maintenance requirements in these spaces.
- Ensure that liquid oxygen storage vessels and distribution systems comply with the requirements specified in NFPA 50 and 29 CFR 1910.104 (designers).
- Implement and follow a plant-specific confined-space entry program designed after the requirements of the Occupational Safety and Health Administration's (OSHA's) confined-space standard in 29 CFR 1910.146.
- Implement a plant-specific hazard communication program for plant operators on the hazardous properties of liquid oxygen. Design in compliance with the requirements of 29 CFR 1910.1200.

CONTROL POINT: Design, Operations, Maintenance

(5) Explosion and Fire Hazards.
Description: Operation of UV oxidation systems can generate gases and build pressure in the process units. There is a hazard for the workers for an explosion and release of the reagents and contaminated materials. Some UV/oxidation systems use liquid oxygen to generate ozone. Liquid oxygen storage creates the potential for fire and explosion.

Control: Controls for explosion and fire include

- Include pressure-relief valves and vents discharged away from the work area (designers).
- Consider including alarm systems, monitors to detect pressure build-up, emergency release systems for head spaces, and emergency plans for operations.
- Train workers in hazards associated with all potential gases generated including ozone odor detection.

CONTROL POINT: Design, Operations, Maintenance

(6) Treatment Buildings.
Description: Permanent or semi-permanent treatment buildings may present life safety hazards such as inadequate egress, fire suppression systems, and/or emergency lighting systems.

Control: Controls for treatment buildings include

- Meet the following construction requirements for permanent and semi-permanent treatment system buildings: ANSI 58.1: Minimum Design Loads

for Buildings and Other Structures; the National Fire Code; the National Standard Plumbing Code; Life Safety Code; and the Uniform Building Code.

- Make sure structures comply with either the Air Force Manuals on Air Force bases, the USACE Technical Manuals on Army installations, or local building codes on Superfund, BRAC, or FUDS sites.

CONTROL POINT: Design, Operations

(7) UV Radiation.
Description: The operation of a UV-based treatment system utilizes lamps that emit UV radiation that may cause eye damage.

Control: A control for UV radiation includes

- Wear the appropriate ANSI-approved eye protection, utilizing the appropriate shade.

CONTROL POINT: Operations, Maintenance

(8) Noise hazards.
Description: Noise hazards may be associated with the use of an air compressor to generate ozone.

Control: Controls for noise hazards include

- Include isolated generator rooms in building design.
- Develop a hearing protection policy in accordance with 29 CFR 1910.95.

CONTROL POINT: Design, Operations, Maintenance

(9) Emergency Wash Equipment.
Description: Emergency shower/eye wash equipment required per 19 CFR 1910.151 is not always provided with adequate floor drains, thereby creating potential electrical hazards or walking surface hazards during required testing/use.

Control: A control for emergency wash equipment includes

- Equip showers/eye wash equipment with accompanying functional drains to isolate and collect the shower/eye washwater from unprotected electrical equipment and walking surfaces that, when wet, create slipping hazards.

CONTROL POINT: Design

(10) Predesign Field Activities.
Description: Predesign field activities associated with subsequent construction may include surveying, biological surveys, soil gas surveys, geophysical surveys, trenching, drilling, stockpiling, contaminant groundwater sampling, and other activities. Each of these field activities may expose the survey personnel to physical, chemical, radiological, and biological hazards.

Control: Controls for hazards resulting from predesign field activities include

- Prepare an activity hazard analysis for predesign field survey activities. EM 385-1-1, Section 1.A provides guidance on developing an activity hazard analysis.
- Train workers in hazards identified.

CONTROL POINT: Design

b. Chemical Hazards.

(1) Mercury.

Description: Workers may be exposed to mercury if mercury vapor-filled lamps are damaged or broken during installation, inspection, or replacement. Mercury overexposure may cause various symptoms including damage to the central nervous system, conjunctivitis, and inflammation to the nose and throat.

Control: Controls for mercury include

- Handle mercury lamps with caution to help prevent breakage.
- Remove mercury spills immediately.
- Make mercury spill kits available in the immediate work areas.

CONTROL POINT: Construction, Operations, Maintenance

(2) Ozone.

Description: Ozone may be produced via an on-site ozonator to enhance the performance of UV oxidation systems. Ozone may leak through seals or pipe junctions, or ozone levels may increase in the work environment if the ozonator fouls. Ozone is a potential experimental tumorigen and teratogen. Exposure to ozone may irritate exposed skin. Depending upon the degree of exposure, ozone may cause irritation of the eyes and respiratory tract, diminished lung function, pain or difficulty breathing, chest tightness, coughing, wheezing, increased sensitivity of the lungs to allergens and bronchoconstrictors, and increased susceptibility to lung-based bacterial and viral infections.

Control: Controls for ozone include

- Use local or general ventilation of the work area.
- Use closed tops and controlled vents on the UV chambers.
- Use gas-tight covers on sumps and holding tanks downstream of ozone generation systems.
- Vent vessels (passively or actively) through ozone decomposition equipment to the outside of the building.
- Interlock equipment with ozone generation equipment.
- Set equipment to shut ozone generation off if plant levels exceed the ACGIH TLV for ozone.

- Install monitors and alarm systems to warn plant operators if plant levels exceed the ACGIH STEL.
- Implement a plant-specific hazard communication program to identify/address the signs/symptoms of ozone exposure including odor identification and to provide procedures for reducing exposures.

CONTROL POINT: Design, Operations, Maintenance

(3) Catalysts.
Description: Worker inhalation/ingestion/dermal exposure may occur during the use of catalysts used in conjunction with UV oxidation.

Control: Controls for catalysts include
- Minimize all contact with catalysts.
- Wear personal protective equipment (PPE) and clothing such as an air-purifying respirator with HEPA (N100, R100, P100) filters, chemically-resistant disposable coveralls, and protective gloves (e.g., nitrile) based on the materials to be handled.

CONTROL POINT: Design, Operations, Maintenance

(4) Hydrogen Peroxide.
Description: Hydrogen peroxide may also be used to help improve the efficiency of UV oxidation systems. Hydrogen peroxide is an oxidizer that may react violently with organic materials either in the waste stream or in other materials, causing fire or system over-pressurization. Exposure to hydrogen peroxide may cause irritation or chemical burns to the skin and damage eyes. Dermal or eye contact with or inhalation of hydrogen peroxide mists or solutions pose a hazard to personnel due to chemical burns associated with acute exposure.

Control: Controls for hydrogen peroxide include
- Require secondary containment for storage of hydrogen peroxide.
- Feed hydrogen peroxide solutions automatically into the treatment system.
- Use PPE if manual addition of the solutions is required. Gloves made of natural rubber or nitrile offer good chemical resistance to solutions of 30-70 percent hydrogen peroxide. Leather and many fabrics, including cotton, rayon, and wool, should not be worn when handling hydrogen peroxide solutions because they present a fire hazard if spills occur. Instead, wear polyester-acrylic (anti-static treated) garments.
- Wear splash-proof chemical safety goggles and face-shields.
- Use local ventilation or respiratory protection to control mists as determined by a qualified health and safety professional.
- Train workers in hydrogen peroxide hazard identification/control.

CONTROL POINT: Design, Operations, Maintenance

(5) Acids and Bases.
Description: Workers may be exposed to pH control agents (acids and bases) during operations.

Control: Controls for acids and bases include
- Construct secondary containment storage areas for acids and bases and use compatible storage materials.
- Mark storage containers clearly.
- Store acids and bases in separate areas.
- Locate emergency showers and eye wash stations that comply with 29 CFR 1910.151(c) and ANSI Z358,1 (1990) near the reagent storage areas.
- Automate handling of pH agents to the extent practical.
- Prepare an emergency plan and train facility personnel to safely handle acids and bases.
- Restrict manual handling of acids and bases to personnel familiar with their properties.
- Use PPE such as leather or rubber acid-resistant boots, chemical-resistant coveralls, goggles and face shields, air-purifying respirators (as indicated by the reagent), and rubber or other acid and base resistant gloves (e.g., nitrile) or gauntlets.
- Train workers in safe acid/base handling techniques.

CONTROL POINT: Design, Operations, Maintenance

c. Radiological Hazards.

UV Radiation.
Description: The mercury lamps used in the treatment generate high levels of UV radiation. Typically, the UV is contained within the treatment unit. However, radiation that is released may damage eyes or increase the risk of skin cancer.

Control: Controls for UV radiation include
- Equip the reactor vessel with interlocks that de-energize the system when the door is opened.
- Equip viewing ports in reactor walls with glass covers that prevent transmission of UV radiation.

CONTROL POINT: Design, Operations, Maintenance

d. Biological Hazards.

No unique hazards are identified.